with the practical certainty that our assignment is only slightly in error.

It is easily shown by thermodynamics that Lord Kelvin's scale is identical with the scale of that nonexistent body, the ideal gas. This substance is defined by the equations

$$(pv)_\theta = \text{const},$$
$$c_v = \text{const},$$
$$\lambda = 0,$$

where p = pressure, v = volume, θ = temperature, c_v = specific heat at constant volume, and λ is the heat effect during free expansion. The determination of the relation of the international scale, or any other gas scale, to Lord Kelvin's scale depends upon the exact knowledge of the variations of the properties of the gas from those of the ideal gas as referred to above. We have no such knowledge for low temperatures, and therefore we are unable, as yet, to make any positive statement regarding "absolute temperatures" below the centigrade zero.

At the other side of the interval of more or less positive knowledge we are, for a certain distance at least, somewhat better off. We may say that gases appear to approximate more nearly to the ideal state as the temperature rises. Therefore, while waiting for more data, especially on the Joule-Thomson effect at greater ranges of temperature, we may have strong hopes that the international scale, even at high temperatures, is not far divergent from Lord Kelvin's scale, our most secure basis for theoretical work. But the gas scale has an upper limit, imposed by the impossibility of procuring a material for the containing vessel, the bulb of the thermometer. Even by giving up the strict adherence to the international scale and substituting nitrogen for hydrogen, it has only been possible to use the gas thermometer with any approach to accuracy up to about 1450°. Above that temperature it is useless to speak of temperatures by the gas scale, because we can not determine them. It is, of course, probable that in time somewhat more refractory materials will be found, so that the upper limit of the gas scale will be somewhat raised; but to pass over this comparatively small advance that may reasonably be expected, suppose we go at once to temperatures approaching that of the electric arc. Not the slightest prospect is in sight that we shall ever determine such temperatures by the gas scale.

What, then, do we mean when we speak of "extrapolating to temperatures of 7000° or 8000°"? The question whether an extrapolation is or is not "allowable," loses all meaning unless we have some means of defining, physically and not merely mathematically, the quantity of which we are finding the value by extrapolation, and a prospect, however distant, of finding out by *direct experiment* whether the extrapolation is allowable or not. If there is no such prospect, the word "extrapolation" is a misnomer. The extrapolation formula is nothing but a new definition of temperature, so arranged as to coincide with some previous definition throughout the range of that previous definition, but independent and standing on its own merits, outside the limits where the validity of the former definition ceases. Thus, one may with some propriety (though perhaps a rather doubtful one) speak of using the thermo-couple to determine temperatures by "extrapolation," because its range is not so much higher than that of the gas thermometer as to preclude all prospect of the possibility of following the thermo-couple with the gas thermometer; but it is, in the writer's opinion, better, even in this case, to admit frankly that, having decided upon a particular thermo couple, and having adopted a formula which connects its indications, at lower temperatures, with those of the gas thermometer, this couple and its formula define a scale of temperature which is for the present independent, though in no sense absolute.

But at such far higher temperatures as we can produce by the electric arc, all our ordinary scales fail, and there is no prospect of their ever doing any service; we are driven to define temperature in some manner independently of the properties, or even the existence of rigid bodies at those temperatures. The most obvious way of doing this, is to turn to the phenomena of radiation, and then, whatever formula we adopt, that formula, together with the *measurable* phenomena to which it refers, constitute a new and independent scale of temperature which may be made to coincide with some other and more familiar scale at some lower ranges of temperature, but which is, nevertheless, in no proper physical sense an extrapolation.

If such a definition can be based securely, and *with no further assumptions of any sort*, upon the laws of thermodynamics, then it is reducible to, and in a mathematical sense equivalent to, Lord Kelvin's scale. If it is founded upon any other principle or principles as general, as exact, and as independent of the properties of particular substances as those two principles appear to be, then it is a new absolute scale. But unless the scale can be defined in some such manner as warrants our giving it the appellation of "absolute," in the sense in which that term has been used in this note, it remains an arbitrary scale, not reducible to any scale of which we have perfect cognizance at such lower temperatures as are ordinarily within our reach.

Our conclusion is, therefore, that it is not allowable to speak of extrapolation to 8000°. Either the scale is an absolute one, valid and having a definite meaning through all ranges where the laws of physics hold, so that there is no need of extrapolation, or the scale is an arbitrary one. If it is arbitrary, it may, as the scale of the thermo-couple may be made to do, coincide with some other scale within a more limited range, but that does not make it an extrapolation formula. If we are not willing to regard the two scales as independent, we can only consider the one of shorter range as being, in a sense, a special and limited case of the one of wider range.

THE INFLUENCE OF LIGHT AND DARKNESS UPON GROWTH AND DEVELOPMENT.

By DANIEL TREMBLY MACDOUGAL, Ph. D., Director of the Laboratories, New York Botanical Garden.

SUMMARY.

By RAYMOND H. POND, Ph. D., dated Sterling, Ill., May 25, 1903.

In the above-mentioned memoir of over three hundred pages (large 8vo.) Professor MacDougal has recorded the most efficient investigation ever made of the influence of light and darkness upon growth and development. The subjects included are, first, the literature, of which a most thorough study is evident; second, experiments in detail with most admirable and appropriate illustrations, including graphic representation of measurements; third, general considerations, comprising critical discussion of experimental data and their interpretation.

The history of physiological investigation reveals the fact that some attention was given to the influence of light upon growth as early as the seventeenth century, but no epoch-making researches were made until the middle of the last century when Sachs undertook his extensive study of the problem. Since the time of Sachs the literature has rapidly accumulated and the failure of previous investigators to reach the conclusions now demonstrated is to be attributed to insufficient and unreliable data as well as to prevailing ignorance of the phenomena of irritability. During a period of seven years, a large part of which was spent working under especially designed facilities, Dr. MacDougal has perfected the technique and accumulated reliable data. Ninety-seven species of plants representing the various systematic groups and covering a wide diversity of growth conditions have been experimented on.

I.—GENERAL CONSIDERATIONS.

Modes of influence of light upon plants.—As a basis for the critical discussion of data experimentally obtained, several pages are devoted to a careful consideration of the various relations sustained by radiant energy, in the form of light, to the physiology of plant life. A distinction must be made between the influence of light upon substances which may be isolated from plant protoplasm and the influence of light upon substances actually concerned in the physiological processes of the living cell. The different changes which may be induced in the latter, are probably less numerous, but certain ones may be regarded as undoubtedly occurring. Among these may be mentioned the oxidation which is known to occur when bacteria are killed by exposure to light; likewise the changes which take place in the enzymes present in the protoplasm.

As in the case of chlorophyl-formation, solar radiation may act as a stimulus to initiate processes without furnishing energy for their operation. As far as available data are concerned, the author believes that the only way in which light might directly influence growth, would be to diminish the production of enzymes essential to the process. It is certainly true that with many plants the rate of growth diminishes under illumination, but a careful consideration of all available data, including that established by earlier investigation, fails to reveal a single instance in which light has directly a paratonic or retarding effect upon growth. On the other hand, well established instances are known in which growth is accelerated when natural illumination is supplemented by artificial light during the night. In such cases, or when plants are removed to Arctic regions for growth under the constant illumination of the Arctic sun, the result to the plant is simply a shortening of its ordinary vegetative period. The denial of customary nocturnal rests, does not result in any distinct modification of structure beyond some slight attenuations in various organs, although some physiological processes seem to be accelerated; at least, certain substances are produced in larger proportion.

In growing toward the light a plant may be seeking not benefit from illumination but the advantages of accompanying conditions which favor its multiplication of individuals. Thus, seeds and spores, which in general are not supposed to be benefited by illumination, secure conditions favorable for dissemination when the reproductive organs are directed toward the light. Moreover, the response to light stimulus may result in enabling the plant to regulate certain physiological processes, such as excessive transpiration. That such reactions are directly caused by the influence of light on the enzymes or other cell constituents, has not thus far been proven.

For each plant there is a minimum, optimum, and maximum intensity of illumination and the length of stem and branch as well as area of leaf surface is, in many species, dependent upon the intensity of illumination. When the intensity of light results in changing the normal stature or extent of leaf surface, modifications of internal structure are likely to occur in response to the disturbed conditions of transpiration or the necessity for mechanical adjustment of the tissues.

The consequences of constant darkness are very marked in comparison with those of continuous illumination. Under constant darkness the inherent tendencies of the plant come to expression, except as modified by gravitation stimulus. Any influence of light to produce modifications in the form of organs or in internal structure, is absent. Thus the necessity for careful consideration of the life habit and nutrition of a plant in the interpretation of its etiolation phenomena becomes apparent. Plants which are accustomed to make their own food by the aid of solar radiation are, under darkness, limited to such nourishment as may be stored in the tissues when the etiolation commences. The stored food is intended to nourish the plant during periods when it is unable to make food for itself, and in amount usually exceeds the probable requirements of such periods, but when light is denied for the entire vegetative season, marked modifications in vegetative form and structure are to be anticipated.

Atrophy may be a consequence of such conditions. Some organs may be suppressed in their development and the tissues used for conveying the nutritive juices of the plant may show marked alterations. The amount of water passing through the tissues is greatly diminished as well as the volume of vapor exhaled from the surface openings. In some plants stomata fail to develop in continued darkness and in such cases the movement of water through the plant is greatly checked. Such consequences of continued darkness are regarded as negative effects to be distinguished from a probable direct influence of darkness, per se, upon the plant.

Underground stems.—When bulbs, tubers, corms, and rhizomes are kept in darkness for the entire vegetative period, quantitative alterations result as an expression of limited food supply. Storage and propagative organs are formed at the close of the season, but they are smaller than the corresponding organs of the parent.

Water plants.—The etiolation of aquatic plants are difficult to interpret because of an apparent tendency to adapt length of stem and leaf stalk to depth of water independently of light influence. Some rooting aquatics were found to exhibit an elongation of petioles and stems in darkness and it seems fairly certain that water plants which send up shoots regardless of the precise water level, correspond with terrestrial species in their response to etiolative conditions. *Philotria canadensis* and *Ceratophyllum* under etiolation show an elongation in internodes even though floating freely.

Endurance of organs and plants under etiolation.—An effort to determine the maximum endurance of plants under continuous darkness was not made, but some cases of extraordinary endurance were observed. Temperature and moisture are very potent factors in determining the endurance under such conditions. Plants vary greatly in their behavior under such environment. In some, as with *Æsculus* and *Hicoria*, the young plants developed an unusual number of internodes whose leaves quickly succumbed, manifesting a constant economy of material in the endeavor to reach the light. In one case a cocoanut made continuous growth for fifteen months using in this time only one-half the stored food supply. In the case of *Canna* the number of foliar organs produced was far in excess of the normal. Plants like *Apios* and *Aristolochia*, which are accustomed to seasonal rest periods, show a characteristic behavior in that the material used to develop etiolated shoots is withdrawn into the storage organ when the etiolated stems die, so that there is no loss of substance except that oxidized in respiration. In underground organs which develop apical buds as in *Arisæma*, *Podophyllum*, and *Pteris*, the old storage organ separates at the close of the vegetative season leaving a new portion like the old. In such cases, attempts to endure may be seasonally repeated and in the case of *Arisæma* an effort was made to persist during four vegetative seasons. With *Arisæma* the proportion of water in the new shoots increases each season, while that in the corms decreases. The potato is capable of forming tubers the second vegetative season under etiolation.

Climbing plants.—In some species only the basal internodes elongate under etiolation, while in others the median ones lengthen more than the basal or apical internodes. It is believed that the number of internodes is not increased over the normal in the case of twining plants though it may remain below normal in some cases. The power of etiolated climbers to twine has not been proven.

Seedlings.—The endurance of seeds having an endosperm depends upon the amount of stored food and resistance of the seed to decay. *Arisæma triphyllum* is able to vegetate in darkness and for three seasons will make vigorous growth in the darkness using only nourishment stored in the seed. In *Hicoria*, which has its food stored in the cotyledons, a peculiar behavior was observed in that after vegetating for the usual period the plant passed through a rest period and resumed growth to the extent of adding several branches. The root system of seedlings under etiolation is usually less extensive than normal.

Effect of darkness upon succulents.—Leaves of the century plant, *Agave Americana*, maintained an apparently normal green color for eight months under continuous and absolute darkness. Immature leaves present when the test began continued to grow at the base of the blade, the tissue formed in darkness being, however, pale yellow and etiolated. Leaves which developed wholly in darkness were completely etiolated and reached only one-half the normal size.

Etiolation of stems of woody perennials.—Twelve different species exhibited a similar behavior in that the buds of their terminal portions were very reluctant to awaken in darkness as compared with buds located on the basal portions of the shoot. In the case of *Fagus Americana*, the buds of young plants would awaken under etiolation, but the buds of mature plants refused to awaken except under the stimulative influence of light. Both young and adult plants of this species readily formed calluses under etiolation, and the buds developing from these calluses grew faster than the control and were able to awaken and develop in darkness as also in light.

Etiolation of stems of herbaceous biennials and perennials.—Many species of such plants do not show an unusual lengthening of the shoot, the internodes just about equaling in number and length those of the control plants. Most of these biennials and perennials have considerable stored nourishment and the experiments show in addition to the dependence of the amount of growth upon the quantity of stored nourishment, also a limited endurance due to the incomplete differentiation of the conductive tissues, and also to the fact that the storage organs usually decay and ferment, thus cutting off the food supply. The diminished transpiration is undoubtedly a factor in the development of the conductive tissues.

Generative tissues.—Examination of the internal structure of etiolated stems revealed notable alterations in the anatomy of plants grown in continuous darkness. Very notable is the modification occurring in *Apios*, whose stem diameter increases, forming in addition to the usual generative layer of tissues in the cambium a second one in the region of the pericycle, which is about one-half as thick as the primary layer.

Etiolation of leaves of monocotyledons with parallel venation.—Most of the plants of this type tested have storage organs in the form of tubers and rhizomes. The aerial stem is practically absent, so that the leaves arise abruptly from the underground stem into a more or less vertical position. There is no striking uniformity in the behavior of these plants under etiolation, although there is a common tendency on the part of the leaves to attain normal dimensions or greater with the usual number of open and probably functional stomata. In some cases, length of leaf is developed at the expense of width, the total surface, however, about equaling the normal. Cases of increase in both width and length were noted.

Inherent inclinations of the plant toward torsions and curvatures seemed to be emphasized while in a few cases plants not usually manifesting such tendencies normally, under etiolation, seemed to acquire them. Probably, however, a part of this result is to be attributed to the disturbed mechanical adjustment of the tissues due to suppressed differentiation and consequent excessive development of the fundamental tissue.

Etiolation of petiolate leaves of monocotyledons with open or reticulate venation.—The behavior of the plants of this group shows features strikingly different from those of the preceding group in that the leaf blades do not unfold while the leaf stalks usually reach an unusual length. In the case of leaves without a leaf stalk, there is not any lengthening of the basal portions of the blade.

Effect of etiolation on leaves of dicotyledons.—Species having storage organs in the form of underground stems or bulbs were selected. The members of this group show a uniform behavior in that they fail to develop leaf blades which are normal, either in size or structure. In some instances the length of the blade increased at the expense of the width, so that the superficial area of the blade was approximately normal. Complete differentiation of mesophyll did not occur. The stomata were usually smaller than normal. Petioles and midribs were greatly lengthened. The leaves manifested very little capacity for endurance.

Etiolation of leaves arising from aerial stems.—Leaves of woody perennial stems differ from those of the herbaceous stems rising from the underground organs, in that those of the former do not attain normal dimensions in darkness, though they may fully unfold and expand. The petioles of such leaves do not lengthen considerably as do those of the herbaceous stems. While such general differences may be noted, it is still impossible to say what factors are determinative in the behavior of plants under darkness, and the most that may be mentioned as yet is, that ancestral habit, food supply, structure of shoot, and leaf are potent in effecting the final result. Leaves resemble stems to the extent that tissue differentiation lags in darkness, causing an unusual proportion of undifferentiated or fundamental tissue, and this partial development in tissue is particularly true of those tissues concerned with starch making, and which, under normal conditions, are accustomed to light exposure. If the quality and amount of development made by leaf rudiments during bud formation is regarded as a factor, it would, of course, be necessary to continue etiolations for two seasons in order to secure complete etiolation, and in this latter case it is very doubtful if any plant can develop leaves which are normal in both width and length.

Effect of etiolation upon spores and sporangia of ferns.—The inclination of tissues to remain undifferentiated, as already considered in the higher plants, is very much emphasized by the consequences apparent in the case of ferns. About eight different species belonging to as many different genera were tested, and it seems that the sporogenous tissue remains so undifferentiated as to prevent the formation of sporangia and the maturity of the spores.

II.—MORPHOGENIC INFLUENCE OF LIGHT AND DARKNESS.

Relation of light and darkness to growth and to differentiation and development.—One prevailing consequence of continued darkness among all species excluding degenerates with chlorophyl, is the decrease in tissue differentiation; a distinct tendency of structural elements to remain in primitive condition being manifest. Tissues, which in normal plants of same age are well differentiated, do not appear in the etiolated. Endodermis and pericycle were altogether missing in the aerial members of perfect etiolations. This means, of course, that the primitive or fundamental tissue is present in greater volume in the etiolated plants.

This absence of differentiation often accompanies growth, so far as increase in volume constitutes growth, showing how very distinct the two processes are. It is thus evident that light has a "morphogenetic" or differentiation-inducing influence upon plant tissue; and the phenomena of etiolation are to be regarded as consequences naturally occurring when this "morphogenetic" influence is withdrawn by the substitution of darkness for light.

Consideration of all the theories hitherto advanced to account for the phenomena of etiolation, reveals them to be altogether inadequate in the light of the comprehensive data accumulated by Dr. MacDougal in the course of this investigation. Etiolation itself is not to be regarded as an adaptation to the absence of light; the extraordinary elongation of stems and branches in darkness is not necessarily an expression of an effort on the part of the plant to reach the light. The phenomena of etiolation are therefore consequences of the withdrawal of the morphogenic influence of light.

Stimulative influence of light.—That light may act as a stimulus to plants has long been known. For each species there is a minimum, optimum, and maximum intensity of radiant energy that may act as a stimulus, so that each species may be regarded as "attuned" to a certain range of light intensity. Development of certain tissues or organs may be entirely suppressed if the plant fails to be exposed to the favorable intensity of illumination. Even the protoplasts may not undergo the customary development if the plant fails to secure exposure to the stimulating intensity required. However, they may continue to multiply as immature elements under the absence of the stimulus necessary to induce their normal transformation. This stimulating influence is not restricted to the particular organ or tissue exposed to it. It may be transmitted causing changes in tissues which were not exposed to illumination while the surfaces which were exposed to the stimulating rays remain unchanged so far as may be determined. Moreover, the stimulating influence may not induce its corresponding consequence immediately, but may remain potential, as it were, producing changes in structure not present in the plant when the stimulus was received. The behavior of *Æsculus* seedlings bears excellent testimony to this latter statement. The seedling of this plant under etiolation does not develop leaves; the foliar organs being represented by mere bracts. If, however, a seedling is allowed to expose its basal internodes to the light and then is confined to darkness, the internodes which develop weeks later will bear leaves.

The results of experiments designed to ascertain the particular influence exerted by certain rays of the spectrum are difficult to interpret. The more refrangible blue violet rays are usually regarded as the ones most effective in producing direction movement, and it is not improbable that these same rays constitute the stimulus which induces morphogenetic or differentiation inducing changes. In all cases the correlation of structure and function must be kept in mind. In some species the leaves are cast away under etiolation and in other species the leaves are retained, making it difficult to say that the shedding of leaves in the former case is an adaptative reaction to the conditions, although it may be, and the reason this does not occur in the latter case is that the organization of the plant disqualifies it to employ such an adaptation.

Likewise, the results obtained by continuous illumination are difficult to interpret in view of the results manifested under discontinuous illumination, and while the generally accepted opinion has been that radiant energy in the form of light may exert a stimulative effect, the supposition may be considered that it may be the influence resulting from an alternation of light and darkness that constitutes the stimulus.

III.—INFLUENCE OF ETIOLATION UPON CHEMICAL COMPOSITION.

Characteristic odors of plants are very much weakened by etiolation, and more delicate flavors may be secured through cultivation in darkness. Economic advantage could no doubt be taken of this fact in many cases, as is now done with some plants, noticeably celery. Cellulose, which resists animal digestion, occurs in diminished proportion in etiolated plants.

Determination of water, dry weight and ash in the case of *Arisæma* showed that the proportion of water present in the corms notably diminishes during the first and second seasons of etiolation; the proportion present in the second being, however, still greater than that in resting corms, air dried at ordinary temperatures. This implies an increased proportion of dry matter, although the actual amount is less. The proportion of ash increases, meaning, of course, the accumulation of incombustible residue. With leaves the water is present in more than normal amount in the first etiolation, and increases during the second season of darkness. The dry matter steadily decreases, while the ash increases.

It is certainly true that etiolated plants absorb mineral salts from the soil.

IV.—RATE AND MODE OF GROWTH AS AFFECTED BY LIGHT AND DARKNESS.

Interpretation of the phenomena exhibited by plants in their periodicity of growth has been by no means uniform. For each plant there is a grand period of growth comprising the interval of gradual acceleration to a maximum rate, and a period of gradual decline to a final minimum rate. The curve which traces this grand period of growth is a very irregular line with many variations presumably dependent upon irregularities in temperature, moisture, or nourishment. In addition to the minor variations mentioned, somewhat rythmically occurring accelerations and retardations may be noted, which are accepted as manifestations of an inherent tendency of the plant. Some investigators have concluded that the rhythmical acceleration and retardation of growth, manifested by plants in the dark room, results as an after effect, or a lingering of the diurnal periodicity, occurring when the plant is naturally exposed to alternation of dry and night. The generally accepted opinion has heretofore been that light has a direct or paratonic effect upon growth, so that the rate of growth increases during the night toward sunrise, and decreases during illumination in daytime. The investigation now at hand, however, shows that the behavior of a given species under etiolation can not be predicted, as would be the case if light per se exerted a universally paratonic influence. The amount of growth, the volume of tissue formed in darkness is much greater so that the stems exceed the normal thickness as well as length in some instances. On the other hand, some species show a decided reduction in the amount and rate of growth under etiolation. The obvious interpretation of these two opposites in behavior is, that darkness as well as light may have a stimulating influence. The stimulative influence of light would account for the tissue differentiation occurring under illumination, while the stimulative influence of darkness would account for the excessive elongation of shoots which occurs in prolonged darkness, and possibly may be regarded as an adaptation phenomenon in some species, indicating an effort by the plant to lift itself beyond an "imaginary obstruction" to illumination. Moreover, when plants are exposed to continuous illumination, that is, when artificial light is used during the night, the amount of growth is greater than in plants naturally exposed to alternation of light and darkness, so that conclusive evidence is now available to demonstrate that light does not have a direct retarding or paratonic influence upon plant growth, nor does radiant energy in the form of light sustain an "invariable and universal relation to increase in length or thickness, or to the multiplication or increase in volume or the separate cells."

The motive of Professor MacDougal in this investigation has been purely scientific rather than economic, but it is to be especially considered that the foundation is now laid for the investigation of problems economically important. Two noteworthy facts of economic significance are mentioned in the memoir, namely, that etiolation may be employed to modify plant flavors and odors and that the proportion of cellulose decreases under etiolation. The latter fact is especially significant because cellulose resists animal digestion, so that vegetables which under light exposure develop a large ratio of this indigestible cellulose be cultivated with proper regard to light conditions so as to become more digestible. Since the particular influence of light upon a given species can not be predicted, and since every plant is "attuned" to a certain range of light intensity, it is evident that the optimum light conditions must be experimentally determined for each species. As soon as this is ascertained, it will then be a very easy matter in view of the comprehensive data constantly accumulating through the observations of the Weather Bureau, to choose a locality, which is known to furnish optimum light conditions. For many years the Weather Bureau has made extensive observations in various regions, not only as to sunshine and cloudiness, but also more recently, as to the thermal effect of solar radiation. The development of research along the lines indicated will make even more apparent the now well recognized public utility of the important facts continually multiplying through the work of the Weather Bureau.

CLIMATOLOGY OF COSTA RICA.

Communicated by H. PITTIER, Director, Physical Geographic Institute.

[For tables see the last page of this REVIEW preceding the charts.]

Notes on the weather.—All over the country, except on the Atlantic coast belt, the weather was unusully dry and close. On the Pacific slope there was a general withering of the vegetation, and owing to the drought and the almost constant wind, the fires, made to burn the fallen trees and trash on newly cleared lands, in many instances spread out, causing serious damage to field and forest. In San José, rain fell on the 23d, 24th, 25th, and 26th, but was scarcely enough to wash away the dust. Pressure and temperature about normal; relative humidity, 66 per cent against 74; sunshine, 255 hours against 205. On the lower hills on the Atlantic watershed, in the San Carlos Valley especially, the scarcity of rain was such that the foliage of the tender plants, growing under the forest shade, was crisp and brittle, and the cacao plantations suffered much damage.

Notes on earthquakes—April 1, 7^h 16^m a. m., slight shock E–W, intensity I, duration 4 seconds. April 2, 10^h 45^m a. m., one shock NW–SE, intensity IV, duration 6 seconds. April 7, 5^h 17^m 45^s, slight shock NNW–SSE, intensity IV, duration 7 seconds. April 20, 3^h 52^m a. m,, slight shock NW–SE, intensity II, duration 4 seconds. April 22, 6^h 47^m p. m., tremors NW–SE, intensity I, duration 4 seconds. April 29, 4^h 40^m p. m., slight shock E–W, intensity II, duration 4 seconds. April 30 5^h 00^m a. m., slight shock E–W, intensity II, duration 3 seconds.

CLIMATOLOGY OF TAMPA, FLA.

By ERIC R. MILLER, Observer, United States Weather Bureau, dated Tampa, May 25, 1903.

Tampa, Fla., latitude 27° 57′ north, longitude 82° 27′ west, is situated midway of the west or Gulf coast of the Peninsula of Florida. It is located at the mouth of Hillsborough River on Hillsborough Bay, the right-hand branch of Tampa Bay, and is about 20 miles from the Gulf of Mexico in a direct line and 35 miles from the bar at the entrance to Tampa Bay.

As regards topography, the city lies on rising ground 10 to 40 feet above sea level. The surrounding region is uniformly low and level or slightly rolling, but is not swampy, as a sandy soil provides natural drainage.

The meteorological history of the station begins in 1825 with the commencement of a record of temperature at Fort Brooke, a military post that formerly occupied the site of the City of Tampa. Measurements of rainfall were begun in 1840 and entries of wind direction and cloudiness were added in 1843. These observations, in a region then the seat of strenuous Indian wars, were made by persons whose duties were mainly military and were frequently interrupted by the more important concerns of the moment. It is to be regretted that such lapses occurred at the time of some very important meteorological events, notably the great freeze of 1835, unquestionably the greatest occurrence of its kind since the occupation of Florida by Europeans; it took place in the midst of a hiatus in the record occasioned by the Seminole war. The Fort Brooke record ceased in 1859, or two years before the opening of the civil war; it was resumed in 1869 for three months, and again during the years 1881–2. W. C. Brown, a civil engineer, acting as voluntary observer for the Smithsonian Institution, kept a record of rainfall for a period covering part of the years 1871, 1872, and 1873. Meteorological observations are also known to have been made for the local newspapers before the establishment of the Weather Bureau office, but no records of these observations have been found. A regular station of the Weather Bureau was established in 1890, and records of all elements have been regularly maintained since April 1 of that year.

The accompanying table exhibits some of the climatological elements. The correlation of these data and the causes of their variation may now be briefly noticed. The weather in winter is more or less modified by passing cyclonic and anticyclonic disturbances, while the weather of summer is mainly controlled by the regular diurnal changes, modified frequently by the occurrence of local thunderstorms and rarely by cyclonic disturbances. The effect of this transfer of the control of the weather from the secondary atmospheric disturbances of winter to the local convectional overturnings of summer upon the temperature is seen only in the character of the disturbances of the diurnal march produced by each, and is not apparent in a climatological table. The rainfall has two maxima, the greater in summer at the time of the greatest frequency of thunderstorms, and the lesser in winter, when the increased frequency of cyclonic disturbances is the source of an increased precipitation. The months of least precipitation, April and November, are those wherein one class of disturbance is gaining and the other losing frequency. Both clouds and wind have winter and summer types, the former being the familiar type of the temperate zones, the latter exhibiting the diurnal changes characteristic of the torrid zone.

Few extreme conditions have occurred since the establishment of the Weather Bureau office that record and tradition do not show to have been exceeded in previous years. The highest temperature recorded since 1890 was 96°, on July 8, 1902, and the lowest 19°, on December 29, 1894. A maximum temperature of 98° was recorded at Fort Brooke in 1848, and it is probable that a temperature as low as 12° or 14° was experienced on February 7–8, 1835, when a minimum temperature of 8° was recorded in the northern part of the State. In the past thirteen years the earliest frost in the fall occurred on October 29, 1892; the first killing frost was on December 6, 1895; the last killing frost March 19, 1892, and the latest frost recorded in spring April 7, 1891. Since the establishment of the Weather Bureau station the greatest rainfall was; for a year, 66.93 inches, in 1894; for a month, 17.83 inches, in August, 1898; for twenty-four hours, 6.56 inches, on September 20–21, 1897; 2.45 inches fell in thirty minutes on June 12, 1900, and of this it is estimated that 1 inch fell in five minutes. In the year 1840 a total of 89.86 inches was recorded; of this 24.52 inches fell in July and 23.40 inches in August, a total of 47.92 inches for the two months. There is a local tradition that the low, flat lands of this portion of the State were under water to the depth of from 1 to 4 feet in 1856, when 22.24 inches occurred in July. There were eighteen successive days with rain in 1894, viz, from August 21 to September 7, inclusive. In 1897 from November 11 to December 4, a period of twenty-four days, there was absolutely no rain, and, if one one-hundredth of an inch be not considered, no rain fell for thirty-two days. April, 1856, is recorded as being wholly without rain. Hail has been recorded at the station only twice in thirteen years, but it has been reported from the surrounding districts a number of times. Snow has fallen three times in the history of the station, and